Peer Review
Experimental Toxicology Division
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PARTICULATE MATTER

Reconstruction of Human Lung Morphology Models from Magnetic Resonance Images

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INTRODUCTION

❖Mathematical models of the morphology of the complex human airway network are of great use in the study of lung deposition patterns of inhaled particulate matter (PM).

❖Such morphological models have been used to analyze and interpret experimental PM distribution data obtained from gamma scintigraphy imaging studies.

❖In addition, these models have the potential to provide a framework for computational fluid dynamics (CFD) simulations of flow and PM deposition in the lung.

❖We present a method for generating a morphological model of the lung boundary derived from magnetic resonance (MR) and transverse single-photon computed tomography (SPECT) images of human lungs.

❖The model is reconstructed from the images using advanced data visualization and modeling techniques.

❖The model can provide an anatomically-realistic framework for the generation of asymmetrical airway models.

METHODS

MR and SPECT Images

❖The imaging study was performed at Southampton General Hospital.

❖Transverse MR images of the lung were obtained from a normal adult male and aligned to SPECT images of the same subject obtained following the inhalation of radiolabeled aerosol with a mass median PM diameter of 6.5 µm.

❖Fifty-two (52) MRI images (**Figure 1**) and 52 corresponding SPECT images (e.g. **Figure 2**) were collected.

Model Reconstruction

❖The morphological model was reconstructed from the MR images using IBM Visualization Data Explorer (DX), a general-purpose data visualization and analysis environment

❖From the binary volume dataset, a surface was extracted at the points at which the data transitioned from 0 (outside the lung) to 1 (inside the lung).

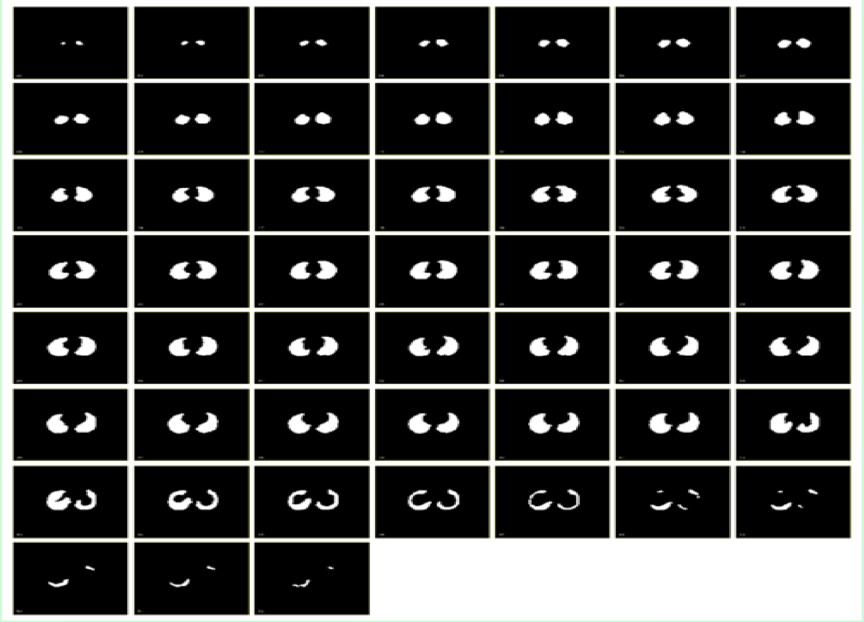

Figure 1. The transverse MR images, spanning the entire lung volume.

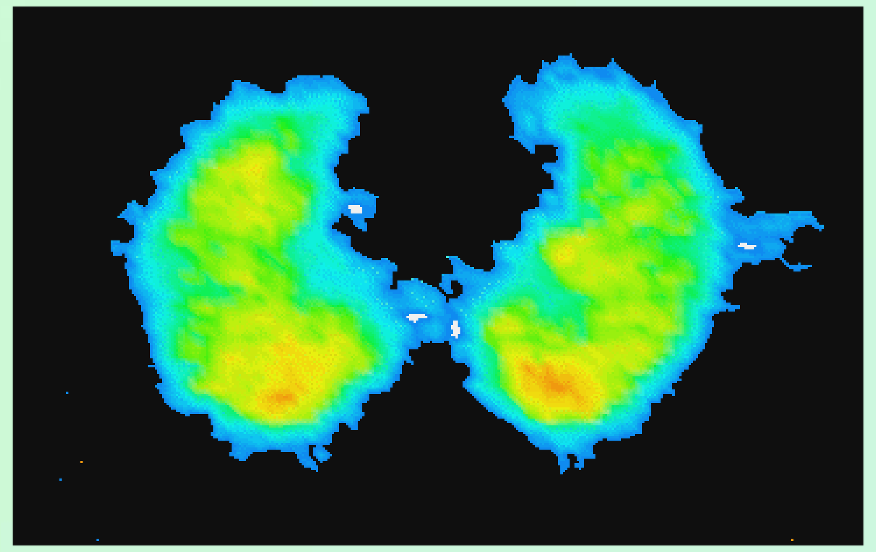

Figure 2. An example of an aligned single photon emission computer tomographic (SPECT) image corresponding to a transverse MR slice.

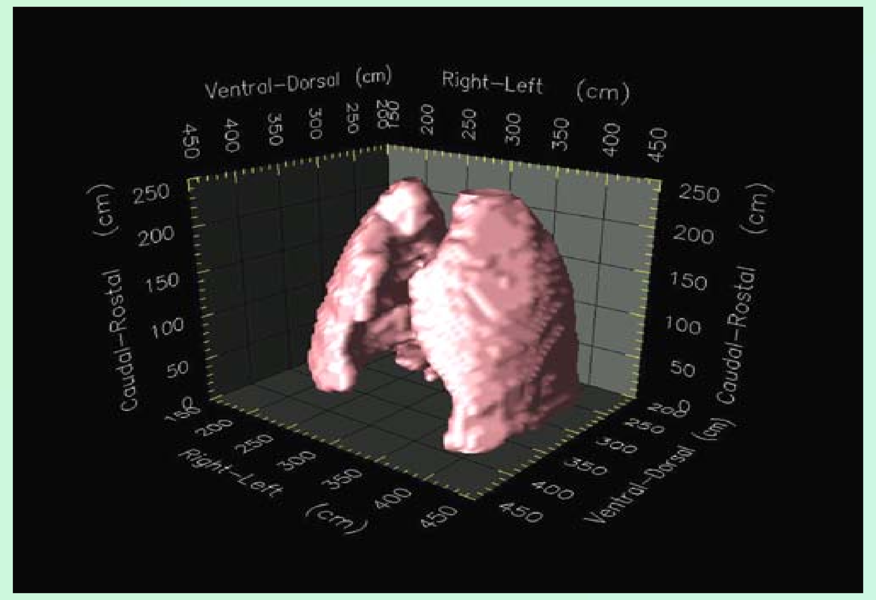

Figure 3. Perspective view of the reconstructed morphology model.

RESULTS

❖Perspective views of the reconstructed morphological lung model (including a coordinate system) are given in **Figure 3** and **Figure 4**. These figures clearly demonstrate the asymmetric geometry of the model about the lung midline.

❖Five examples of the transverse model cross-section are given in **Figure 5**. The asymmetry of the cross-sections, particularly near the base of the lung, is evident.

❖ **Figure 6** and **Figure 7** show sagittal and orthogonal sections of the lung morphology model, respectively.

❖The model presented here demonstrates a marked increase in anatomical realism when compared to previous morphological models used in the generation of human airway models.

❖These methodologies could be used to generate volume and section visualizations of 3D regions associated with a particular level of aerosol deposition from SPECT data.

❖The MRI-based morphological lung model can provide a framework for generating anatomically realistic models of the branching human airway network.

❖The model can be used to define a lung boundary for our mathematical branching network airway model (**Figure 8**).

❖Aligned SPECT images could then be associated with the lung model (**Figure 9**), and PM deposition (as measured by the intensity of the radioactivity) could then be associated with individual airways of the branching lung model (**Figure 10**).

❖The morphological model presented here, in conjunction with an associated branching airway model, could be used as a foundation for CFD simulation of airway flow, PM transport, and PM deposition. These CFD studies would allow us to study the fate of PM for a wide variety of particle sizes and respiratory conditions.

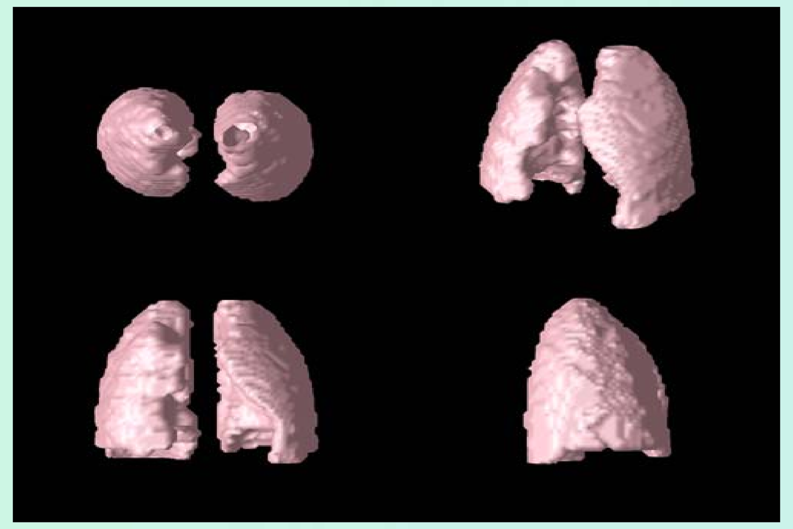

Figure 4. Top, perspective, front, and side views of the lung model.

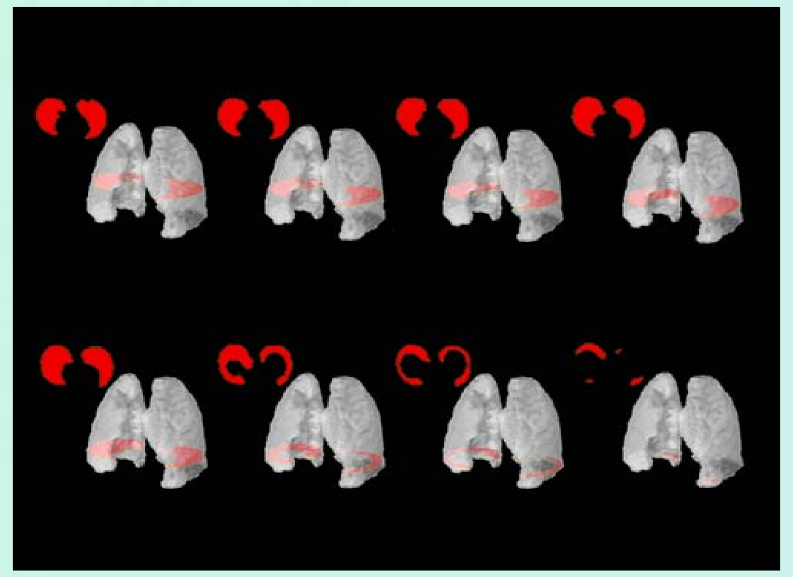

Figure 5. Transverse cross-sections of the lung model. Note asymmetry about the lung midline and variation in cross-sectional shape.

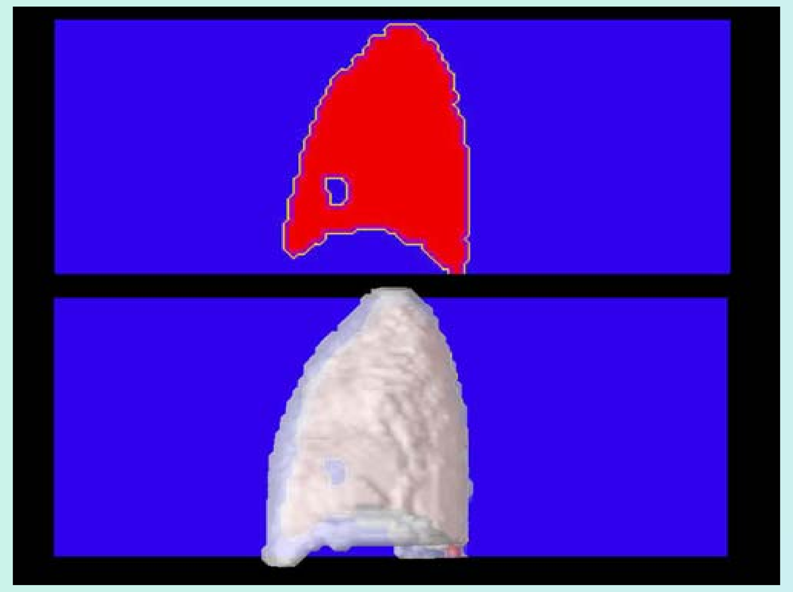

Figure 6. Sagittal section of the reconstructed morphology model**.**

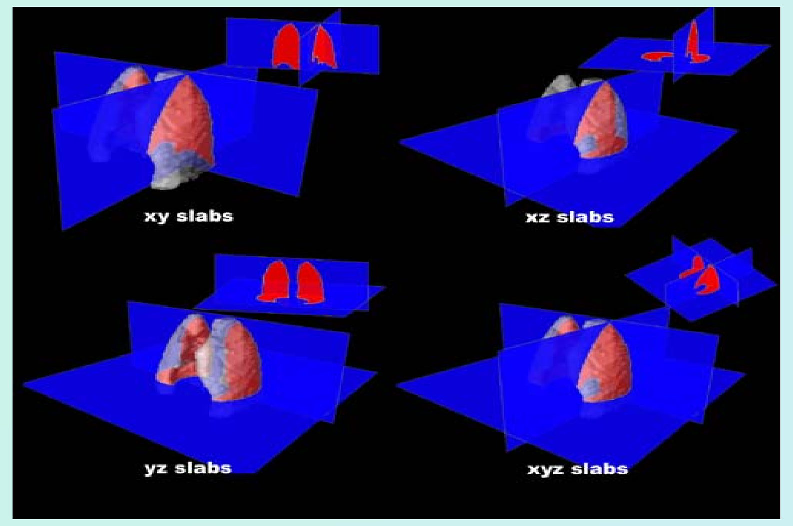

Figure 7. Various orthogonal sections of the lung model.

Figure 8. A branching lung network model bounded by the MRI-based lung model.

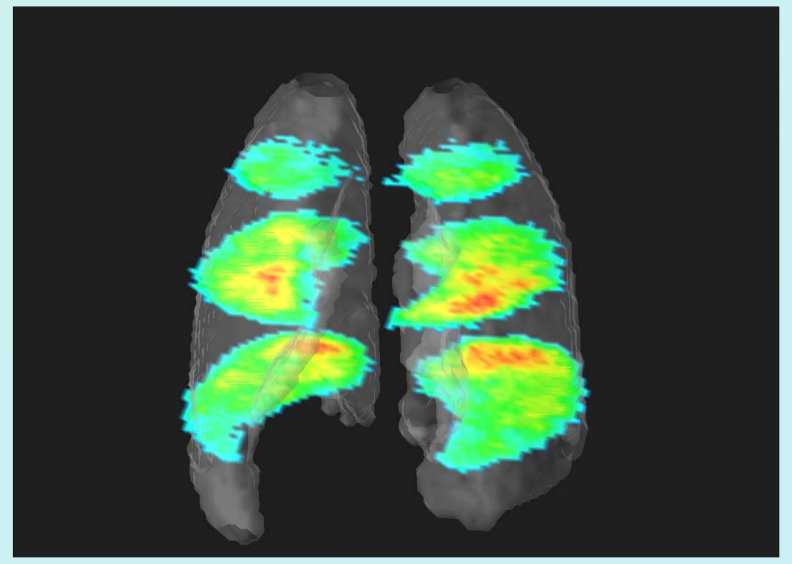

Figure 9. The MRI-based lung model and the corresponding SPECT data for a single slice.

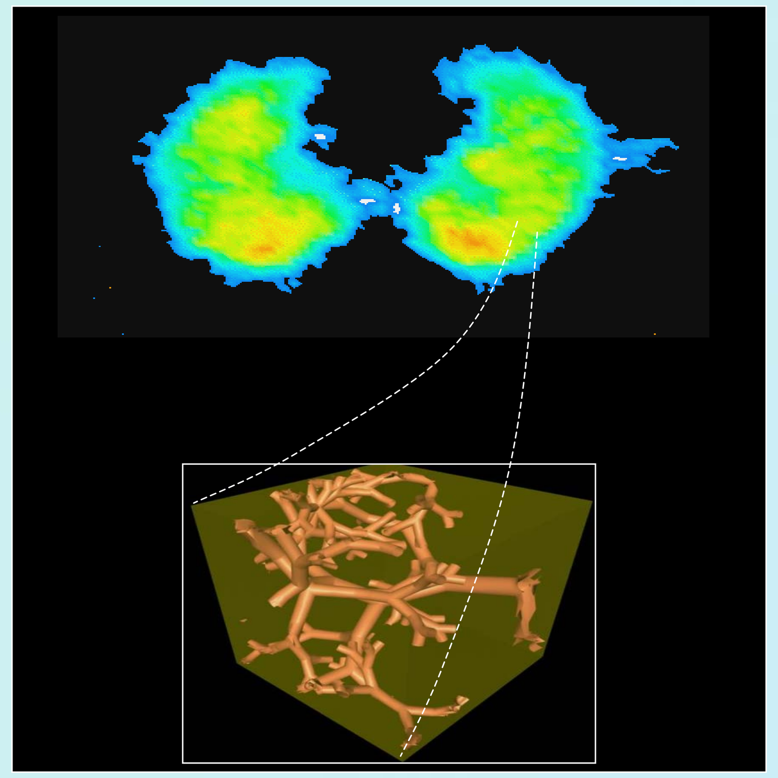

Figure 10. Association of the airways of the branching lung model with a single voxel of a SPECT slice (and its corresponding radioactivity value.)

CONCLUSIONS AND IMPACT

❖The model provides a mathematical description of the lung boundary that can be used in conjunction with a computational model of the branching structure of human lungs to produce realistic, asymmetrical models of the entire lung airway system.

❖The resulting models would have an immediate use in inhalation toxicology research, as they could be applied both to the CFD modeling of PM deposition in the lungs and to the interpretation of experimental SPECT data.

FUTURE DIRECTIONS

❖The mathematical models and related computer codes should become evermore anatomically correct so that any associated PM dosimetry & PBPK software programs become evermore biologically realistic.

❖We shall focus on key factors that have been identified to be integrated in the mission of the EPA as related to the adverse health effects of PM airborne pollutants.

❖To increase the relevance of future anatomical models/codes, we shall endeavor to use real data from human imaging studies:

- MRI
- SPECT
- PET

❖To apply the models/codes to issues of concern to the EPA we shall consider the following sensitive subpopulations:

- Age Effects
  - Children
  - Elderly
- Respiratory diseases
  - Asthma
  - Emphysema
  - Chronic Obstructive Pulmonary Disease (COPD)

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